The TREND IN ENGINEERING

at the University of Washington

Special issue

Graduate Program and Research Review

ENGINEERING RESEARCH—KEY TO THE FUTURE

THE EXPERIMENT STATION IN RELATION TO THE GRADUATE PROGRAM

AERONAUTICAL ENGINEERING

CHEMICAL ENGINEERING

CIVIL ENGINEERING

ELECTRICAL ENGINEERING

MECHANICAL ENGINEERING

CERAMIC, METALLURGICAL, MINING ENGINEERING

ENGINEERING GEOLOGY

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THE ENGINEERING EXPERIMENT STATION

THE NATURE OF CREATIVE THINKING*

The Philosopher:

"Socrates defined the philosopher as a thorn in the flesh, and nobody is a creative thinker unless continuously he has a thorn in his flesh, that is, unless he is disturbed by something. . . . Creative thinking consists in being sensitive to that disturbance, in staying with it and analyzing it and finally coming up with some kind of speculative answer which is then confirmed by empirical, and preferably experimental evidence. It is the essence of all creative work that it always involves a jump into the dark, in order to come up with a possible answer to the problem that is a thorn in one's flesh."

—F. S. C. Northrup, *Sterling professor of Philosophy and Law, Yale University.*

The Scientist:

"First of all, the thing which is the essence of creativity is the decision to do something about it when you are irritated. I would agree that irritation is the first step; but the decision to do something about it—that is the essence of creativity. The conditions favorable for making such a decision include, of course, an opportunity to understand what the possibilities are, freedom and facilities to make use of the opportunities, and a setting in which one feels the real importance of doing what one sees may be done. To be a creator in research one must decide for himself what he is going to do, because nobody else can tell the research man what it is that he should do. Give him freedom and give him the necessary equipment to do with reasonable ease the things that he needs to do."

—A. H. Compton, *Chancellor, Washington University, St. Louis.*

The Artist:

"The most fruitful parallel between our creative functioning is in our concept of structure. . . . By structure I do not mean, for the painter, the composition or architectural aspect of his canvas, or, for the scientist, his simply observed and recorded pattern. I mean the informing idea or spirit behind the pattern which holds all the elements in place. The movement which the physicist plots in the atom and fastens down with an equation, the pattern the biologist perceives in cell growth and tracks with a formula, the pattern the painter perceives in nature or in himself and fixes on the canvas, is first found by searching for the animating structure which links separate phenomena and gives them meaning. . . . Creation can be defined as a trained intuition which carries within it its own control. . . . Creation is a successful step into the unknown. The key word is successful."

—John Ferren, *painter, New York City.*

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*Excerpts from the Symposium presented at the May 5-7, 1952, meeting of the Industrial Research Institute, Skytop, Pennsylvania, and sponsored by Industrial Research Institute, Inc.

THE ENGINEERING EXPERIMENT STATION of the University of Washington was established in December, 1917, to coordinate investigations in progress and to facilitate the development of engineering and industrial research in the University. Its purpose is to aid in the industrial development of the state and nation by scientific research and by furnishing information for the solution of engineering problems.

The scope of the work is three-fold:

(1) to investigate and publish information concerning engineering problems of a more or less general nature that would be helpful in municipal, rural, and industrial affairs;

(2) to undertake extended research and to publish reports on engineering and scientific problems;

(3) to provide opportunities for graduate engineers to conduct research under conditions that will most effectively prepare them for professional service.

For administrative purposes the work of the Station is organized into nine divisions:

1. Aeronautical Engineering
2. Chemical Engineering, Industrial Chemistry
3. Civil Engineering
4. Electrical Engineering
5. Forest Products
6. Geology
7. Mechanical Engineering
8. Mining, Metallurgical, Ceramic Engineering
9. Physics Standards and Tests

The control of the Station is vested in a Station Board consisting of the President of the University, the Dean of the College of Engineering as chairman, the Director of the Station, and members of the faculty, representative of the administrative divisions. The Board determines the character of the investigations to be undertaken and supervises the work.

The Station offers a substantial number of research fellowships to highly qualified graduate students who work under the direct supervision of the faculty of the various divisions. Results of major investigations are published in the form of bulletins and reports. Current research findings from the Station's fellowship projects, as well as accounts of its activities, appear in the quarterly journal, *The Trend in Engineering at the University of Washington*. Reprints of articles by members of the engineering faculty and graduate students published in recognized technical journals are also issued by the Station. Requests for copies of the publications and inquiries for information on engineering and industrial problems should be addressed to the Director, Engineering Experiment Station, University of Washington, Seattle 5.

October, 1953

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at the University of Washington

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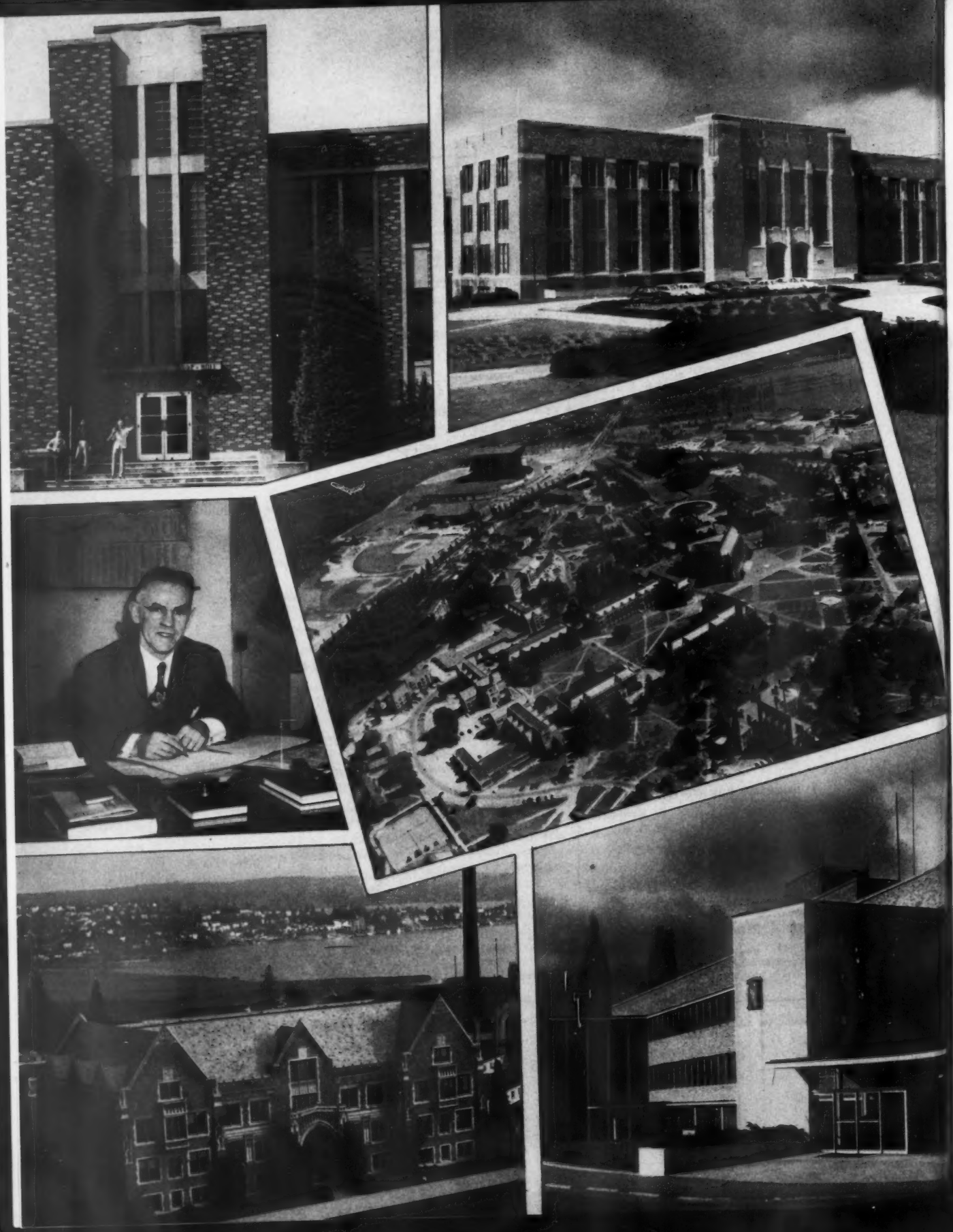
FRONTISPIECE

Shown clockwise from upper left are C. C. More Hall *(Civil Engineering);* Bagley Hall *(Chemical Engineering);* Electrical Engineering Building; Guggenheim Hall *(Aeronautical Engineering);* Dean Harold E. Wessman of the College of Engineering. *Center:* Air view of the University of Washington campus.



Engineering Research--Key to the Future

HAROLD E. WESSMAN
Dean, College of Engineering

SEVEN PUBLICATIONS, a typical sampling from the mail of recent weeks, are spread out before me on my desk. Their titles alone are enough to stir the imagination of laymen as well as engineers:

"Atomic Power Just Around the Corner"
"Radio Relay—A Modern Application of a Familiar Principle"
"Reclamation's Golden Jubilee"
"Automatic Control—The Role of the Computer"
"Beyond the Sound Barrier"
"Underground Gasification of Coal"
"The Free Piston Gas Turbine Engine"

Space does not permit recounting the fascinating story of research, development, design, and production associated with each one of these subjects. We now know that atomic power is practical and feasible, that the generation of electricity on a commercial scale from nuclear energy is much closer than most engineers would have predicted only two years ago. We learn that at the heart of the radio relay network across the land is a remarkable electronic tube, the "Mighty Midget," a tube small enough to be concealed in the palm of your hand, with parts requiring unbelievable manufacturing precision.

To anyone in the Pacific Northwest, "The Golden Jubilee of Reclamation" means the unfolding miracle of the Columbia Basin, where a desert area three-quarters the size of the state of Delaware is being converted to "green pastures" to make a better living for a growing population. Basic research in civil, electrical, and mechanical engineering, supplemented by basic agricultural research has made such projects possible. We read of the fantastic developments in the automatic control of industrial processes being made possible by electronic computers, more familiarly termed "mechanical brains." We read of the problems which had to be solved or are being solved so that airplanes may safely surpass the speed of sound. We are informed that underground gasification of coal, though still in the experimental stage, may make it possible to convert low-grade coal reserves, which are difficult and costly to mine, into usable energy or into chemical constituents. The free-piston engine is the story of an idea which was hatched over eighty years ago but which is only now arousing considerable interest in this country. Intervening developments in gas turbines have opened the way to a variety of commercial applications of the simple free-piston unit. The story of this engine demonstrates graphically the importance of continuous and creative technical research to convert an idea into a useful product.

Collectively, these articles involve every field of engineering research. Implicit in every story is the record of mathematical analysis, laboratory experiment and hundreds of tests; of trial and error and retrial; of temporary defeat and discouragement; of technical and manufacturing ingenuity. These articles, and many like them which come through the mail in a bewildering array, testify to the significant role of engineering research and development. It is engineering research which bridges the gap between basic research in the sciences and product design and manufacture in a particular industry. The common tendency to characterize all engineering research as applied research is misleading because engineering research has no boundaries. It merges imperceptibly at one end into the basic research in mathematics, physics, chemistry, and at the other end into the development and design of a product that can be manufactured, marketed and sold.

It is generally a long trail which leads from fundamental research to a marketable product with a practical use. Almost fifty years ago the mathematician Einstein derived the famous equation, $E = MC^2$, which gives the relation between energy and mass, but it was not until December, 1942, that the physicist Fermi demonstrated its practical application when he successfully initiated a nuclear chain reaction in his uranium and graphite pile at the University of Chicago. In fact, it is just recently that successful pilot plants have been built for the generation of electricity from atomic power.

Much of the research behind the few developments listed in this paper was initiated in the colleges and universities of our country. Their responsibility for conducting basic research transcends regional boundaries. We must not forget that basic engineering research today means new industry in the future, industry to maintain the economy and well-being of state and nation.

Many people become impatient with research because they look for an immediate practical answer. Charles F. Kettering, the General Motors genius,

has said, "In research in engineering we have to think five, ten, fifteen, or twenty years in advance because it sometimes takes that long for us to develop a new idea so that it can be made into a product."

Engineering research, in fact all research, is the key to our future in more ways than one. The prosperity of our nation and our high standards of living depend upon the research of our scientists and engineers. In fact, our national security itself hinges upon the degree to which basic research is encouraged and supported with adequate funds.

No one is better qualified to point this out than the former Chief of Staff, General Omar Bradley, who, in a recent article in the *Saturday Evening Post*, states, "Our surest protection, in my opinion, lies in steadily increasing our scientific and technological lead over the Soviet bloc, and in the widest application of such knowledge to our military defenses. . . . I would like to put in a word for basic research, which usually promises no immediate results. Such pure or basic research is hard for the layman to understand, yet is absolutely essential for our future scientific progress. If too many of our scientists are put to solving immediate practical problems, our vaunted scientific lead will 'run out of gas.' . . . Shortsightedness may fatally mortgage our future."

The Engineering Experiment Station in Relation to the Graduate Program

F. BURT FARQUHARSON

Director, Engineering Experiment Station

"The desirability of research in colleges and universities is generally recognized, but the idea that research is an essential feature of a true university is not always accepted. . . . A 'community of scholars' does not make a university unless the scholars are creative scholars; teachers who limit their activities to the collection and dissemination of facts may serve a purpose, but they are not of the stuff that makes a university. . . .

Research is the lifeblood of the university departments of science and technology. The activities of teaching and research are natural complements, and the combination teacher and research worker is apt to be a better research worker than one who does no teaching and a better teacher than one who does no research. The 'research professor' who does no teaching has no more place on a university faculty than a teacher who has no interest in any type of research."

—Dean Thomas K. Sherwood*

DEAN SHERWOOD'S JUSTIFICATION OF RESEARCH in educational institutions embodies the philosophy underlying the establishment of a graduate program in the College of Engineering, fully integrated with the operation of the Experiment Station.

Thirty years after its establishment in 1917, the Engineering Experiment Station was expanded in 1947 to take its part in the Engineering College's first serious venture into graduate work. This expansion coincided with the erection of two new engineering buildings and, for the first time in its history, the College found itself in a position to consider seriously a fully rounded program in the graduate field.

The acquisition of the expanded facilities was paralleled by adding to the various departments instructors qualified by training and experience to conduct the advanced research in their respective fields, an essential concomitant to a vital graduate effort.

Geographical isolation and lack of a record of experience in advanced work (except in chemical engineering) called for special efforts if the transition was to be accomplished without undue lag. Expanded space and additional staff were not alone sufficient; research facilities adequate for the demands of a vastly expanded technology, and a generous supply of the raw stuff of the research staff, namely, graduate students, were essential. The expanded Experiment Station, designed to assist in this transformation, thus took on certain unique characteristics.

* From a paper presented before the Engineering Division of the Association of Land Grant Colleges and Universities, at Kansas City, October 24, 1949. Quoted from *Chem. Eng. News*, Feb. 13, 1950.

Through a special bill the 1945 Legislature appropriated $24,000 which was earmarked for the subsidizing of twenty graduate engineering students at the rate of $1,000 per individual. The additional $4,000 was made available for incidental laboratory expense. During the 1945-47 biennium, thirty individual graduate students were granted fellowships under the provisions of this bill, and fourteen received Master's degrees during this biennium. From this original group, an additional nine graduate students received Master's degrees in the fall of 1947.

Encouraged by the promising results of this small experiment in advanced studies, a much enlarged request was included in the 1947-49 budget. The administration and the Legislature responded generously, and provision was made for extending the fellowship arrangement and also for the addition of certain items of equipment without which the graduate program would have been greatly handicapped.

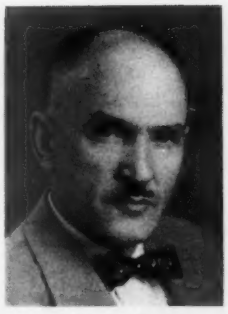
It was judged that a maximum of economy and avoidance of duplication between departments would develop if such expenditures were processed through the Engineering Experiment Station whose governing board includes the heads of all degree-granting departments of engineering, under the chairmanship of the Dean of the College.

Following 1947, research fellowships were granted on a fifteen-month basis, with one-half time devoted to an assigned research project and the remaining effort applied to formal academic courses, and with a thesis built around the research project. Every effort has been made to bring together a graduate student, a supervisor and a project which in combination form a complete working arrangement, and in which considerable responsibility rests on the student.

The full-fledged effort which was initiated following the 1947 legislature coincided with the influx of veterans of World War II, and during the year, 59 graduate students were awarded fellowships. By the year 1950, the total number of Station fellows had increased to 85, of whom 22 received their subsidy from sponsored projects. The impact of the Korean War was felt with particular force in engineering education, with the result that the year 1952 found the fellowships reduced to 44, of which eight were attached to sponsored projects.

Since 1946, Experiment Station Fellowships have been granted to 250 individual students, five of whom have obtained the Ph. D. degree in Chemical Engineering, and 164 the degree of Master of Science in their respective departments.

Of the 81 recipients of fellowships who failed to obtain degrees, by far the largest proportion were casualties resulting from the war situation following June, 1950. However, a significant number of these will obtain their degrees in the near future.



F. B. Farquharson

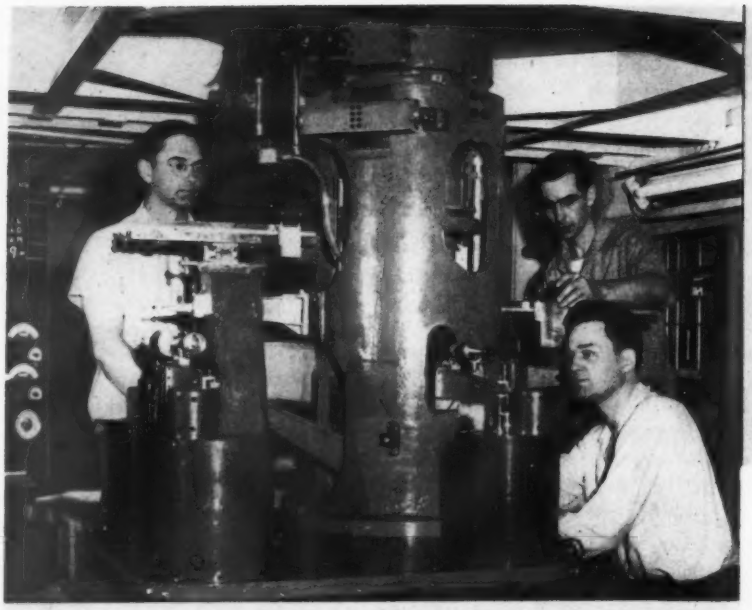
In addition, 27 graduate students obtained degrees while working on projects subsidized by outside agencies, of whom four obtained the Ph.D. in Chemical Engineering.

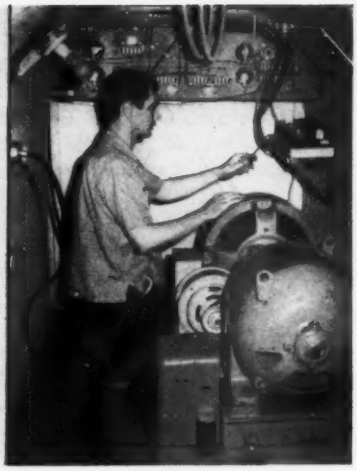
The balance of the 401 advanced degrees obtained during this ten-year period (205) were granted to regular graduate students in normal pursuit of advanced training. Although this report covers activities spread over the last ten years, the impact of the war was such that very few advanced degrees were granted until 1947. The accelerated activity following the war was sharply curtailed in 1951, owing to new international tensions.

The modern laboratory makes use of a steadily increasing quantity of electronic measuring equipment, utilization and maintainance of which is a constant problem; morever, delays arising from instrumentation failures are costly and vexing. For the past seven years, the Experiment Station has operated an Electronic Measurement and Control Project designed to serve the instrumentation needs of the Engineering College. During this period the division has designed and built numerous items of special equipment and in addition has acted in an advisory capacity to many projects. This has proved to be of inestimable value.

Besides serving the College of Engineering, the electronic division has also performed many services for other divisions on the campus. These include the Departments of Psychology, Meteorology, Physiology, and Geology, the Schools of Medicine and Dentistry, and the Fisheries Research Institute.

One major problem which has plagued all research laboratories in these days of high educational operating costs has been the great temptation to accept elaborate government research contracts as a means of supporting a large research staff. The College of Engineering of the University of Washington has accepted only moderate sized contracts from government agencies, and always with the stipulation that they must contribute to education. The criterion applied in accepting sponsored research has, again, been admirably stated by Dean Sherwood as follows: "In my opinion the most important condition is that the nature of the project be such as to permit student participation, normally in the form of student theses. It seems to me that where student participation is excluded the objective of full integration of research and education is defeated at the outset."





Above

Left: Remodeled balance system of wind tunnel. *(L. to r.)* Prof. R. G. Joppa and research engineers, R. H. Smith and L. B. Gratzer.

Right: Motor-generator set providing power for attack-change drive motor; Mr. Smith adjusting controls on angle-setting servo-mechanism.

Below

Calibration rig where airplane model would ordinarily be mounted for testing. Smith and Joppa are applying known loads to test the balance system.

Aeronautical Engineering

V. M. GANZER
Executive Officer

V. M. Ganzer

The research contributions of the Department of Aeronautical Engineering since World War II have been almost entirely confined to the fields of aerodynamics, structures, and dynamics. Aerodynamics, of course, is usually identified with aeronautical problems, and much of the laboratory equipment of the department has been developed to service this field of research. Structures and dynamics, on the other hand, are by no means peculiar to aeronautics, but many unusual problems in these fields have arisen in aircraft applications, and the opportunities for research have been almost limitless. Problems such as the stresses in thin, flexible, swept wings; development of extremely light structures; the dynamic behavior of aircraft, including effects of flexibility; and many others, are examples.

With one possible exception, the paths followed by the Department of Aeronautical Engineering in performing research and tests are similar to those followed by all of the engineering departments in the College. These paths consist of sponsored research, which may include the use of graduate students; non-sponsored research by the staff; Engineering Experiment Station projects, which are always carried on by graduate students under departmental staff supervision; and theses for advanced degrees. The possible exception is the F. K. Kirsten 8′ x 12′ wind tunnel, which will be discussed later.

Also in common with other departments, the Department of Aeronautical Engineering has performed services such as consulting with industry, participating in professional society activities, serving on various committees, and others.

Seven sponsored research programs resulted in reports ranging from purely experimental papers, such as the study of boundary-layer control in diffusers, to complex mathematical studies in non-linear differential equations. These projects were carried on by ten different staff members, including almost all of the available staff. Two National Advisory Committee for Aeronautics Technical Notes 2563 (Ganzer and Cole) and 2895 (Lin and Street), resulted from some of the studies.

Non-sponsored research is attested by the list of articles appearing in various journals and magazines, and by the University of Washington Aeronautical Laboratory (UWAL) reports, sixteen of the latter being issued between 1943 and 1951. These, too, are diverse in content, but the several papers on cycloidal propulsion might remind one that much of the original work on this subject was done in this department, and that the major patents in this field were held by Prof. F. K. Kirsten. This work, in amended form, is still being carried on in the study of the problems of flight through a large speed range, including hovering or near-hovering, and recent activity and interest show that this problem is becoming more important every day. Another subject of these reports is the design, construction, and testing of the supersonic wind tunnels and allied equipment.

Reference to the list of titles shows that one Experiment Station Bulletin (Prof. R. M. Rosenberg, editor) was published, consisting of eleven papers. Eighteen Experiment Station projects were worked on by graduate students. Forty-five theses for the Master of Science in Aeronautical Engineering degree have been written since 1948.

The F. K. Kirsten 8′ x 12′ wind tunnel has been of especial service in its dual role as a research tool for faculty and students, and as a tool for the use of airplane manufacturers in the development of new aircraft. In the latter role, it has been of service to a host of aircraft companies, including Boeing, Lockheed, McDonnell, Consolidated, North American, Vultee, and others. Models of many famous airplanes, such as the Boeing Flying Fortress, Superfortress, Stratocruiser and Stratojet, the Lockheed Lightning and Constellation, the McDonnell helicopters, and many others, have been tested in the wind tunnel during the development of these airplanes. Since its operation began in 1939, the wind tunnel has conducted 265 tests of this nature, averaging from one to six weeks each, for twenty-one different companies. The value of the availability of this wind tunnel to the aircraft industry during World War II and in the rapid post-war development of aircraft has been inestimable. The use of the tunnel for this type of testing is still continuing, and many aircraft of the future are being tested on the University of Washington campus today.

Consequences of the use of the wind tunnel by industry have been expansion of the aeronautical laboratories with the derived revenue, and part-time employment for many students, both graduate and undergraduate, who otherwise might not have been able to attend the University.

A recent development in the F. K. Kirsten wind tunnel was the modernization of the balance system designed by Prof. F. S. Eastman. This work was completed in the summer of 1953, the expense being borne jointly by the Boeing Airplane Company and the University. The original balance system, although much copied in later wind tunnels, was designed to fit the needs of the type of testing done in 1939 and 1940. New and different techniques of wind-tunnel testing demanded that the balance system be revised to make the laboratory useful for modern testing, and with the present system the tunnel should be of even greater value as a research and development tool than it has been in the past.

The staff of the Department of Aeronautical Engineering has been active throughout the years in consultation with industry. Aside from summer employment and the wind-tunnel activity, regular consultation with the Boeing Airplane Company, the Aerocar Company, the agricultural airplane interests in the state, and the Armed Services, has been carried on.

In the last five years, the department has had one chairman and two vice-chairmen of the Seattle Branch of the Institute of Aeronautical Sciences. Two staff members are on national scientific committees, and two members have served on reviewing boards for scientific journals.

Publications: 1948-1953

Books

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Engineering Experiment Station Bulletins

EES Bulletin No. 118, *Investigations in Aeronautics from the Department of Aeronautical Engineering*, edited by R. M. Rosenberg, 119 pages, 1951.

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LIN, T. C., "The Effect of Variable Viscosity and Thermal Conductivity on The High-Speed Couette Flow of Semi-Rarefied Gas."

———, **(with L. G. Whitehead),** "The St. Venant Torsion Problem for the Hyperbolic Airfoil Cross Section."

———, **(with H. T. Yang),** "The St. Venant Torsion Problem for Cross Sections Consisting of One Loop of the Hyperbolic Limacon."

MARK, R. M., "Application of the Extended Karman-Tsien Method for the Generation of Conventional Airfoils in Two Dimensional Subsonic Compressible Flow."

MARTIN, H. C., "An Instability Problem Arising in Uniform Cantilevered Struts."

———, **(with H. J. Gursahaney),** "An Observation Regarding the Deflections of Uniform Swept Cantilevered Plates."

ROSENBERG, R. M., **(with H. P. Durand),** "A New Approach to the Design of Metering Pins in Oleo Struts."

———, **(with K. P. Abichandani),** "Aileron Flutter in a Single Degree of Freedom."

———, **(with A. J. Wang),** "Periodic Solutions of a Nonlinear Differential Equation."

———, "The Influence of Axial Torques on the Critical Speeds of Uniform Shafts in Self-Aligning Bearings."

STINE, H. A., "The Flat Plate Laminar Boundary Layer in a Steady Accelerated Compressible Fluid."

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BROWN, J. H., "Design for a Schlieren Apparatus," *The Trend in Engineering*, Vol. 2, No. 2 (April, 1950). *(Grad. Student).*

GANZER, V. M., "Experimental Investigation of Rolling Performance of Straight and Sweptback Flexible Wings with Various Ailerons" **(with H. A. Cole, Jr.),** NACA Tech. Note 2563 (Dec., 1951).

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LUECK, D. W., "Ordinates for Axially Symmetric Supersonic Nozzles" **(with A. J. Wang),** *The Trend in Engiing*, Vol. 2, No. 1 (Jan., 1950), *(Grad. Student).*

MARTIN, H. C., "Elastic Instability of Cantilever Struts Under Combined Axial and Shear Forces at the Free End," *Proceed.*, First U. S. National Congress of Applied Mechanics, 1951.

———, "A Superposition Method for Calculating the Aeroelastic Behavior of Swept Wings" **(with R. B. Brown and K. T. Holtby),** *Jour. Aer. Sci.*, Vol. 18 ,No. 8 (Aug., 1951). EES Reprint No. 54.

———, "On the Deflection of Swept Cantilevered Surfaces" **(with H. J. Gursahaney),** *Jour. Aer. Sci.*, Vol. 18, No. 12 (Dec., 1951). EES Reprint No. 59.

———, "Research on Swept Wings," *The Trend in Engineering*, Vol. 2, No. 1 (Jan., 1950).

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STREET, R. E., "Effect of Variable Viscosity and Thermal Conductivity on the High Speed Slip Flow Between Concentric Cylinders" **(with T. C. Lin),** NACA Tech. Note 2895 (Feb., 1953).

Graduate Theses: 1948-1953

M.S. in Aeronautical Engineering

EES: Engineering Experiment Station Fellow

1948

CARLSON, R. M.: Design Applications of the Shear Lag Theory.
HACKETT, T. J., JR.: Determination of End Fixity for Columns in a Testing Machine.
JEFFS, G. W.: The Effects of Airplane Flexibility on Horizontal Gust Loads.
OLIVER, R. B.: A Fuel Consumption Study of the Ramjet Engine.
SCROGGS, A. M.: Spanwise Distribution of Airloads on Swept-back Wings for Both Subsonic and Supersonic Speeds. (EES)

1949

HAMILTON, W.T.: An Aerodynamic Longitudinal Stability Criterion Applicable at High Subsonic Speeds.
HATTE, R.: An Investigation into the Nature of Airplane Control System Friction. (EES)
KNECHTEL, E. D.: A Solution of Saint Venant's Torsion Problem for Circular Arc Airfoils. (EES)
LEDBETTER, G. E.: A Design Study of Low-Density Supersonic Wind Tunnels.
MCDEVITT, J. B.: A Study of Rarefaction Waves with Application to the Starting of Wind Tunnels.
PHELPS, G. M.: An Investigation of Equal-Strength Design of Incomplete Diagonal Tension Field Beams. (EES)
ROSSMAN, E. A.: Equations of Motion and Response of an Airplane in a Gust.

1950

CHANG, K. T.: The Hodograph Method in Subsonic Flow Past Airfoils. (EES)
CHENG, H-C.: Development of Deflection Functions Suitable for a Rayleigh-Ritz Solution of Certain Cantilever Plate Problems.
CHU, W-H.: Theories of the Shockwave Structure in One-Dimensional Steady Flow. (EES)
COLE, H. A., JR.: Determination of Rolling Characteristics of Flexible Wings with Sweepback by Matrix Methods. (EES)
CROSSFIELD, A. S.: Theoretical Swept Wing Aerodynamic and Longitudinal Stability Characteristics.
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"Our species is the only creative species, and it has only one creative instrument, the individual mind and spirit of a man. Nothing was ever created by two men. There are no good collaborations, whether in music, in art, in poetry, in philosophy. Once the miracle of creation has taken place, the group can build and extend it, but the group never invents anything. The preciousness lies in the lonely mind of a man."—JOHN STEINBECK in *East of Eden*.

Chemical Engineering

R. W. MOULTON
Executive Officer

R. W. Moulton

The graduate research program of the Department of Chemical Engineering has expanded greatly during the past ten years. We now have about thirty-five graduate students compared with three in 1943, and we now have five full-time permanent faculty members compared to the equivalent of 2½ persons ten years ago. All of our staff are active and interested in research in chemical engineering. Some of the most important research contributions are described in the following sections.

Pulp Mills Research

The Pulp Mills Research Project was established in 1944 at the University of Washington by about twenty pulp and paper companies located in the state of Washington as an instrument to aid in the development of methods by means of which the discharge of pulp and paper waste materials into watercourses and the atmosphere could be avoided. The investigation was supported to the extent of about $50,000 per year until 1949 and since that time has been granted $20,000 per year. Dr. J. L. McCarthy directs the chemical engineering division of this project.

One part of the research effort has been expended in the study of methods which might be immediately applicable for disposal or utilization of such materials as sulfite waste liquors and the kraft mill odor substances. Many methods have been considered and brought to the attention of representatives of the industry. Some results have been reported in the literature and other work is in progress or being prepared for publication.

The second part of the research effort has been concerned with the longer term problem of development of additional useful facts concerning lignin: its removal from wood, its purification and chemical characterization, its derivatives and conversion products, and its utilization. Study has been devoted to lignin sulfonic acids from sulfite waste liquors, and also to sulfur-containing lignins similar to those available from kraft pulping waste liquors. Methods suitable on a laboratory scale for purification of some of these liquors have been evolved. Their elementary composition as available from Pacific Northwest woods has been determined. Several new methods for characterization of lignins have been worked out and are being applied to lignins isolated under different conditions. Some chemical derivatives of these lignins have been prepared and their properties are being determined. Lignin reactions which may have industrial and theoretical significance are under study.

Some results from the work have been given in about sixty papers reported in the literature or presented at scientific and technical meetings.

Research Highlights

BECK, THEODORE RICHARD, "Electrode Electrolyte Temperature Difference," M. S., 1950 (supervised by Dr. G. L. Putnam). Mr. Beck was able to show conclusively that during electrolysis there may be very significant temperature differences established between the electrode and the electrolyte. In the past most research workers in this field have been unaware of these differences. The electrode temperature is usually more significant than the electrolyte temperature as far as the chemical reactions which occur during electrolysis.

BUCKHAM, JAMES ANDREW, and STUELPNAGEL, T. R., "A Correlation of Theoretical and Experimental Temperature Distribution in High-Frequency Dielectric Heating," M. S., 1948 (jointly supervised by Prof. W. R. Hill, of Electrical Engineering, and the writer, representing Chemical Engineering). These graduate students studied the temperature distribution achieved during high-frequency dielectric heating of non-conductors. This method of heating has certain marked advantages over other methods for materials of poor thermal conductivity. The heating is rapid and uniform. It was shown that the actual temperature distribution checked reasonably well with the theoretical distribution as calculated from the laws governing heat transfer.

CHITTENDEN, JOHN STRONG, "Recovering Alumina and Iron from Oregon Laterite," M. S., 1948 (supervised by the writer). The laterites of Oregon represent a large and important mineral resource. Mr. Chittenden worked on an electric furnace method of recovering both iron and alumina from these ores. He showed that a partial separation of the two compounds could be achieved. Further work should be done to evaluate the economies of this method.

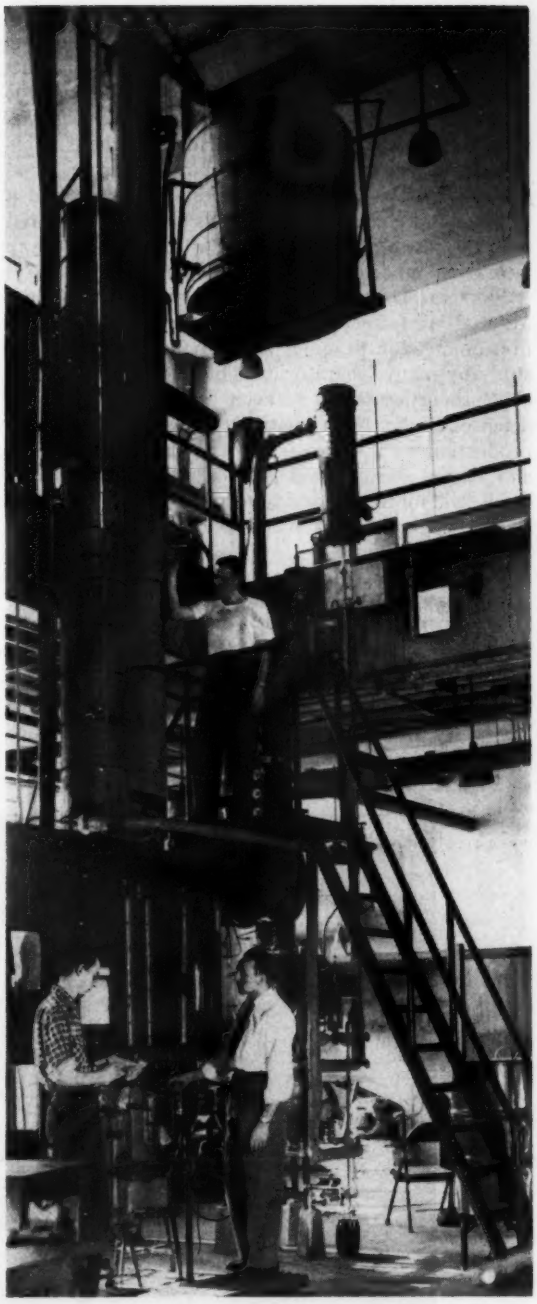
COOK, MARSHALL W., and ELGERT, OSCAR J., "Cascade Liquid-Liquid Fractionation: A New Unit Operation," M. S., 1950 (supervised by Dr. J. L. McCarthy). These two students worked on a new and novel method of liquid-liquid extraction. This important unit operation has many possible applications. The process depends upon the difference in partition coefficients for the components being separated in a given binary solvent pair. Further work is underway in this field.

EVANS, ROBERT WALTER, "Complete Gasification of Southwestern Washington Coal by a Continuous Water-Gas Process Employing Oxygen and Steam," M. S., 1948 (supervised by the writer). Mr. Evans made studies on a process for the complete gasification of low-grade Washington coals. This project has great importance for the coal-mining industry of this state. Mr. Evans showed that it was possible to treat our local coals by this method. Work is continuing in order to further improve this process.

FETTERLY, LLOYD COCHRANE, "Study of Kinetics and Equilibria of Ureafatty Acid and Related Complexes," Ph. D., 1950 (supervised by the writer). Mr. Fetterly developed an entirely new method for the separation of certain kinds of organic compounds. He showed that urea and thio-urea formed crystalline complexes with some organic compounds and did not with others. He was able to accomplish the separation of compounds which previously had been practically impossible to separate. This work has had great commercial interest. There are now upwards of thirty patents in this field.

GREAVES, GROVER SPENCER, "Fusion of Rock Phosphate with Magnesia and Silica," M. S., 1947 (supervised by the writer). Mr. Greaves demonstrated that a phosphate fertilizer could be prepared by the electric furnace fusion of phosphate rock and olivine. This allows for the economical production of a fertilizer from local raw materials and electric power. This work was in part supported by funds from the Bonneville Power Administration. Several large plants have been built during the past five years utilizing this process, both in this country and abroad.

GREENFIELD, HAROLD, "The Chlorination of Olivine Ore," M. S., 1948 (supervised by the writer): There are very large reserves of the magnesium mineral, olivine, in this state. However, the magnesium is combined chemically with silica in a manner which makes it extremely difficult to recover. Mr. Greenfield showed that chlorination of olivine would result in the formation and volatilization of magnesium chloride. This is the magnesium salt which is commonly used by the major magnesium producers of this country as a raw material for electrolysis. If the economics of this process could be worked out satisfactorily, this would be an important local industry.



EQUIPMENT FOR STUDY OF SULFUR DIOXIDE ABSORPTION ON A SEMI-WORKS SCALE

Above: **Lyle Gordon, E.E.S. Fellow.** *Below:* **Stuart Lovell** *(left)* **and L. A. Lundberg, E.E.S. Fellow.**

MULVANY, PAUL KENNETH, "Studies Concerning the Rates of Adsorption and Desorption of Some Low Molecular Weight Hydrocarbons and Their Binary Mixtures," Ph. D., 1950 (supervised by the writer). Mr. Mulvaney showed that activated charcoal was an extremely good adsorbent for hydrocarbons. This adsorbent can be readily manufactured from wood available in the Pacific Northwest. He completed a rather comprehensive study in this field and measured both the rate and the amount of adsorption for many pure compounds and mixtures of compounds.

PASTELL, DANIEL LOUIS, "Electrolytic Titanium," M. S., 1947 (supervised by the writer). The production of metallic titanium is receiving very intensive study by many laboratories. This metal has remarkable properties which make it of importance to the defense effort. Most methods used today for the production of the metal from its ores are complex and costly. Mr. Pastell studied the electrolysis of fused salt mixtures, and showed that this operation showed promise as a method for the reduction of titanium compounds.

STANTON, LYMAN SHUMWAY, "Continuous Separations by Ion Exchange," M. S., 1950 (supervised by Dr. J. L. McCarthy). Ion-exchange is becoming increasingly important as a unit operation. Most commercial ion-exchange columns are of fixed bed type. Mr. Stanton showed, as a result of work in this laboratory, that it was possible to make a moving bed ion-exchange column. This has a very distinct advantage in that the process is continuous in operation. His work is being continued by other graduate students.

STULTS, FREDERICK CHARLES, "The Kinetics of the Condensation of Formaldehyde with Sodium p-Phenol Sulfonate in Aqueous Solution," Ph. D., 1950 (supervised by Dr. J. L. McCarthy and the writer). Mr. Stults studied the kinetics of the formation of a phenol-formaldehyde type polymer. He built a pilot-plant unit for the continuous production of this type of product. Operation of this pilot-plant equipment verified his calculations. Most commercial production of resins of this type is now accomplished in batch kettles. If the continuous operation proved commercially feasible this would be a marked contribution to the industry.

TURNER, GILBERT MEREDITH, "Spray Droplet Size-Frequency Distribution for Hollow-Cone Nozzles," Ph. D., 1950 (supervised by the writer). Spray drying is a unit operation of importance to many different industries. Most of the work that has been published on this topic is rather empirical in nature, and lacking in detail. Mr. Turner has as an object of his work a fundamental study of the rate of heat transfer and mass transfer during spray drying. In order to make this study it was necessary to first determine the average drop size and the distribution of drop sizes when spraying through hollow cone nozzles. Mr. Turner's work presents the results of his study and gives the background for additional work in this field.

EXPERIMENTAL SETUP FOR STUDY OF HIGH-FREQUENCY DIELECTRIC HEATING

L. to r.: **J. A. Buckham, Prof. W. R. Hill, T. R. Stuelpnagel. Buckham and Stuelpnagel were E.E.S. Fellows. Professor Hill was the electrical engineering supervisor for this joint project.**

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Graduate Theses: 1945-1953

Ph.D. in Chemical Engineering

DP: DuPont Company Fellow
EES: Engineering Experiment Station Fellow
PG: Proctor & Gamble Company Fellow
SOC: Standard Oil Company of California Fellow

1950

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FETTERLY, L. C.: Study of Kinetics and Equilibria of Urea-fatty Acid and Related Complexes.
MULVANY, P. K.: Studies Concerning the Rates of Adsorption and Desorption of Some Low Molecular Weight Hydrocarbons and their Binary Mixtures.
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KOENIG, W. W.: Continuous Countercurrent Ion Adsorption and Stripping Using Ion Exchange Resins. (PG)
LI, P-S.: Unsteady-State Mass Transfer from Gas Bubbles; Liquid-Phase Resistance.
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M.S. in Chemical Engineering

EES: Engineering Experiment Station Fellow
GE: General Electric Company (Hanford) Fellow

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(Continued on page 40)

Above

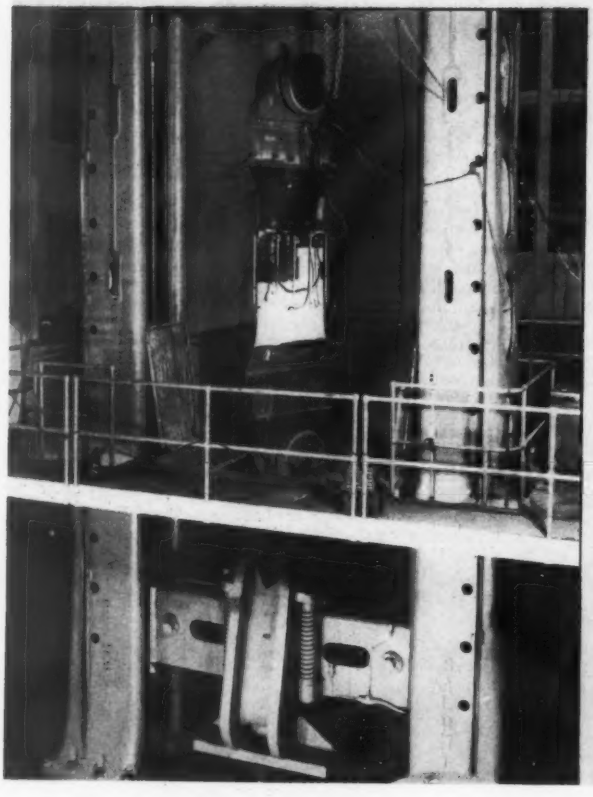
Model used in designing Hell's Gate fishways which enable salmon to mount rapids. *L. to r.:* the late Fred J. Foster, Commission member, Professors H. K. Moritz and C. W. Harris.
(*Photo courtesy*, SEATTLE TIMES)

Below

Left: **Structural testing machine (2,400,000-lb capacity) with 3'x7' plate specimen being tested in tension.**

Right: **Ben K. Rippe, E.E.S. Fellow, pouring paving mixture into Triaxial Institute Compactor, with Prof. R. G. Hennes, supervisor of the project.**

Note oscilloscope added to original design to permit observation of time-pressure distribution.



Civil Engineering

R. B. VAN HORN
Executive Officer

R. B. Van Horn

The research program of the Civil Engineering Department is operative on the following general policy:

1. The research program should provide strong support for undergraduate and graduate instruction and should be carried on under the direction of the teaching faculty.

2. The magnitude of the research program undertaken should not exceed that which can be directed effectively by the teaching staff.

3. Primary emphasis in the engineering research program should be placed on the advancement of the engineering sciences and the development of new and more reliable methods of analysis and design.

4. Developmental research should be encouraged as a part of the over-all program so long as it is not extended to place the University's facilities in competition with those of private firms in this field.

5. Exploratory or background research is necessary and desirable as a basis for the formulation of the objectives of engineering research.

Because of its broad professional base, the department's activities do not stop with its instruction and research. It serves industry and the citizens of the state in many ways, and the public contacts of its staff are wide and varied. These may range from the simple telephone call asking for technical advice or information to extremely complex problems of a professional or scientific nature. Some of this work is on a consulting and/or contract research basis, but the majority is gratuitous and often requires a financial contribution by the individual because of the travel involved.

The research activities of the department are spread over five divisions, and a total of 83 master's degrees were granted between 1946 and 1953. Of these graduate students, 46 were recipients of fellowships, of which 39 were carried by the Engineering Experiment Station, with the remaining seven partially subsidized from sponsored projects.

Some of the major research activities of the department which involve full or partial sponsorship from outside sources will be listed as follows:

Hydraulic Division

The major laboratory and design work on the Hell's Gate Fishway (largest in the world), on the Fraser River in British Columbia, was conducted under the supervision of Prof. C. W. Harris, with the assistance of Prof. H. K. Moritz on mechanical phases, and Prof. A. L. Miller on structural design. The project, sponsored by the International Pacific Salmon Fisheries Commission, resulted in the construction of similar fishways at Bridge River Rapids and Farwell Canyon. According to the Commission's report, the Fraser River sockeye run for 1952 contributed $8,232,000 more to the economy of Canada and the United States than in 1947, the preceding cycle year.

Professor T. H. Campbell, in cooperation with Dr. P. E. Church, executive officer of the Meteorological and Climatological Department of the University, has been conducting a streamflow forecasting project under the sponsorship of the Bonneville Power Administration. It is contemplated that this project, which deals with the entire Columbia basin, will be of long duration and of very vital importance to the region in its over-all power problems.

Sanitary Engineering Division

Wide distribution has been given to the following reports, written for the State Pollution Control Commission, by Professor R. O. Sylvester:

"Puget Sound Pollution—Seattle Metropolitan Area," 1949
"A Report on the Willapa River Estuary," 1950
"An Investigation of Pollution in the Yakima River Basin," 1951
"The Sewage Disposal Problem in the Seattle Metropolitan Area," 1952

Professor R. G. Tyler has been active in the fields of air pollution and water supply, as well as sewage and waste disposal. While he was in charge of the Disposal Project of Pulp Waste Research* the treatment of sulfite waste liquor was intensively studied. Air-pollution investigations were conducted for the cities of Tacoma and Seattle (the latter in cooperation with the Environmental Research Laboratory at the University), and numerous communities have been served in connection with their sewage and water-supply problems. The Sanitary Laboratory has been especially active in developing a process for the ozonization of sewage.

* See report of the Chemical Engineering Department.

Structural Division

The failure of the Tacoma Narrows Bridge precipitated a series of investigations which are still in progress, under the direction of Professor F. B. Farquharson, with the assistance, during certain phases, of Professor F. C. Smith. Early investigations were supported by the Washington Toll Bridge Authority, but eventually the Bureau of Public Roads joined in the sponsorship. In the later phases of the investigation, the University of Washington and the Bureau of Public Roads have divided the costs. The studies have been conducted under the direction of the Advisory Board on the Investigation of Suspension Bridges. Twenty-nine progress reports have been made to this Board, and three parts of a five-part publication, issued as Bulletin 116 of the Engineering Experiment Station, have been printed. Parts IV and V are about to go to press.

The laboratory which grew out of the Tacoma investigations has also been used in connection with other problems. In 1951 the effect of wind on corona discharge was investigated at the request of the Bonneville Power Administration. In 1952 a series of aerodynamic studies were conducted on the Golden Gate Bridge at the request of the Golden Gate Bridge and Highway District..

Professor R. A. Hechtman has supervised three sponsored research programs in the Structural Research Laboratory which are described below. All three of these projects are still active.

1) Welded Reinforcement of Openings in Structural Steel Members: sponsored by the Bureau of Ships, Navy Department. Four progress reports have been submitted.

2) Lateral Buckling of Rolled Steel Beams: sponsored jointly by the Column Research Council and the University of Washington. Three progress reports have been released.

3) Slip of Structural Steel Double-Lap Joints Assembled with High-Strength Bolts: sponsored jointly by the Washington Toll Bridge Authority, the Research Council on Riveted and Bolted Structural Joints, and the University of Washington.

Following the severe earthquake in the Northwest in 1949, Professor A. L. Miller has been active in the seismological organizations of the Pacific Coast, and is a member of the Advisory Committee on Seismology of the U. S. Department of Commerce.

Transportation Division

Professor R. G. Hennes was requested by the Governor to represent the University on the Washington State Council for Highway Research at the time of its establishment in June, 1951, and was at once elected chairman. The purpose of this Council, composed of eight members representing various groups concerned with transportation problems, is to correlate and classify all highway research resources in the state of Washington for the solution of the state's highway transportation problems. The research facilities of both the University of Washington and the State College of Washington have been used, along with those of other agencies. Whenever possible, student help has been employed.

Two reports, "State Interest in Highways," a report on highway classification in two volumes, and "Feasibility of Toll Roads in Washington," were released in January, 1953.

Projects now active include:

1) Natural Resource Roads Study
2) Use of Agricultural Soil Maps in Road Building
3) Application of WASHO Test Data to Washington Roads
4) Allocation of Motor Fuel Tax Revenue Among Counties
5) Highway Cost Allocation.

Publications: 1943-1953

Engineering Experiment Station Bulletins

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CHENOWETH, H. H., "Relative Pipe Roughness" **(with R. E. Leaver),** *Jour. Am. Water Works Assoc.*, Vol. 43, No. 3 (Mar., 1951).

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M.S. in Civil Engineering

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GRAY, V. O.: A Preliminary Investigation of Thin Reinforced Concrete Wall Strips Subjected to Buckling Loads.
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MESARA, H. R.: Analysis of Accelerograms.
OLSON, K. F.: Evaluation of Meteorological Factors Affecting Atmospheric Pollution in Seattle.
OZSEZEN, Y. K.: Sidesway Displacement Due to Earthquakes.
RATTI, D. B.: Structural Behavior of Post-tensioned Concrete Beams. (EES)
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FOX, R. R.: An Investigation of the Effect of Partially-rigid Joints on the Secondary Stresses in Trusses.
ILAGAN, C. O.: A New Consolidation Test for Clay Cores.
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SAVIKKO, E. R.: Structural Steel Bolted Joints Under Short-Time and Sustained Loading. (EES)
SCHOLEN, D. E.: Hydraulic Jet Air Ejector for Ozonating Drinking Water. (EES)
STYER, E. F.: Lateral Buckling of Rolled Steel Beams with Semi-Rigid End Connections. (EES)
TURKLAP, ISMET: Structural Behavior of Beam and Column Joints in Reinforced Concrete Building Frames.
WANG, T. P.: Factors Affecting Structural Behavior of Post-tensioned Concrete Beams. (EES)
ZIA, Z. T.: The Use of Air-Permeater for Determination of Porosity of Bituminous Paving Mixes. (EES)

M.S. in Engineering

1951

GREEN, A. W.: Selected Studies of General Atmospheric Pollution in the City of Seattle, Washington.
ISAAC, P. H.: Groundwater Flow at Partially Penetrating Interceptors.

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HSIA, HUNG: An Investigation of the Effect of Distribution of Reinforcing Steel Bars upon Warping of Reinforced Concrete Slabs.
LYON, C. R.: Characteristics of Fish Processing Wastes.
QURAISHI, F. R.: Bituminous Soil Stabilization for Irrigation Canal Linings.
ROLLER, J. A.: Effects of Chlorine and Salt Concentrations on the Relations Btween Bacteriophage and Dieaway of Coliform Organisms.
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Electrical Engineering

AUSTIN V. EASTMAN
Executive Officer

A. V. Eastman

The research and professional activities of the Department of Electrical Engineering have been manyfold during the last ten years. This is indicated in part by the increase in staff from seven in 1943 to sixteen in 1953, but even more by the number of recent publications.

The research efforts of the department have been largely grouped under several main headings, although a number of smaller projects have been undertaken, in most cases at the request of individuals or firms looking for assistance in promoting Washington state industries, or as a result of the realization by some staff member that a need for certain studies existed in the state.

Professor George Smith has devoted a considerable amount of research to the heat pump as a means of using electric power for heating homes and buildings in a manner which is competitive with other sources of heat. This study, sponsored in part by the Bonneville Power Administration, was started when it was believed there would be an excess of electric power in the Northwest. This work has provided information concerning the ground area required to provide an adequate source of heat from ground grids; the suitability of wells, lakes and streams as heat sources; and some information on the extraction of heat from air. The results have been thoroughly reported in the technical literature.

Another field of intensive study is that of radio propagation. There are a number of reasons why the topography of the Pacific Northwest makes computation of expected field strengths from proposed radio stations extremely difficult. This problem was early recognized by the department, and studies were undertaken without outside sponsorship by Prof. V. L. Palmer, who has since left the University. The work has been continued by Prof. H. M. Swarm, who has attracted national attention by the results of his work. In addition to his general studies in this field, he has carried out some special assignments for local television broadcasters and, in cooperation with Dr. A. E. Harrison, for commercial telephone interests, making recommendations, as the result of extensive field studies, concerning the location of their transmitters to provide maximum service to the public. Because of Professor Swarm's success in this field, the National Bureau of Standards in 1951 requested him to conduct certain field-strength measurements as a part of a nation-wide study. This work is still continuing.

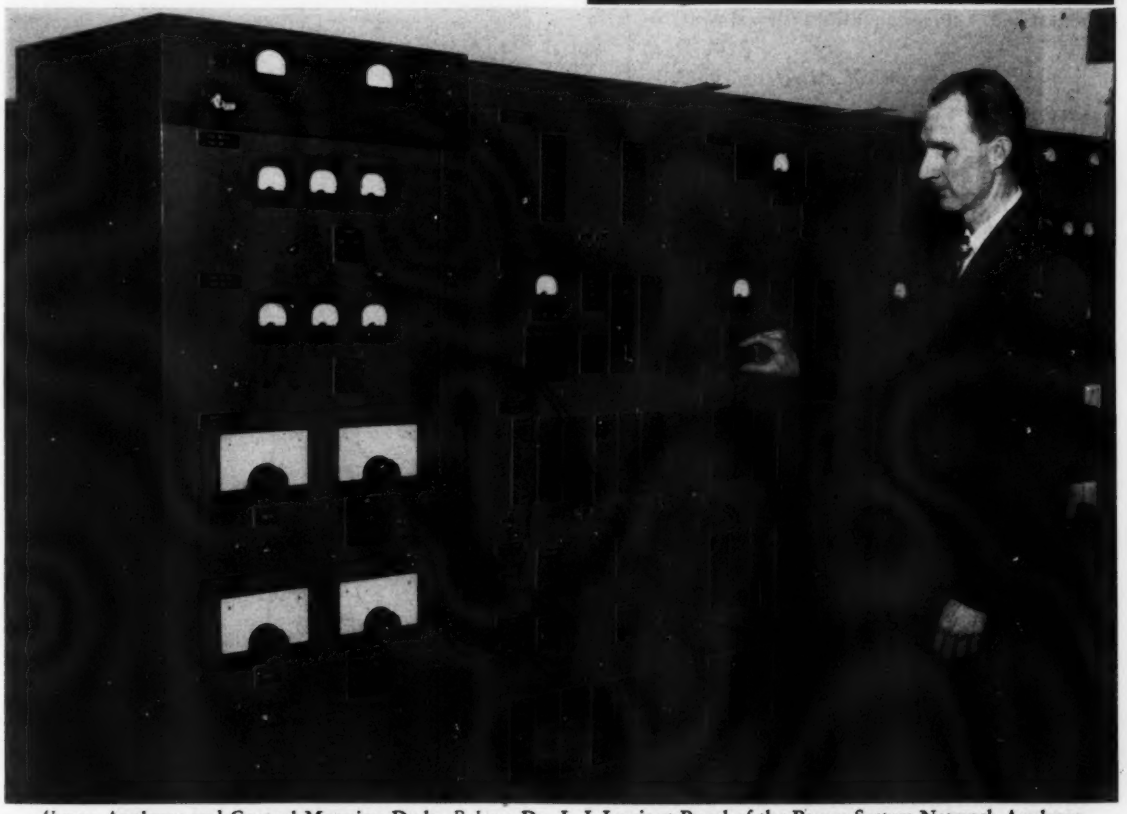
Another field of interest which is of much importance today is that of microwaves. A program has been in progress for some years under the supervision of Dr. A. E. Harrison, sponsored in large measure by the Office of Naval Research, to determine the extent of cross modulation in traveling wave tubes and to develop suitable methods of measurement. This is a problem of vital importance in the design of receiving systems operating in the microwave region, and the results of this work should lead to improvements in the design of equipment for these high frequencies.

Work on servomechanisms and computers, a subject of studies by Prof. T. M. Stout, has been largely sponsored by the Office of Naval Research. An important phase of this problem has been concerned with increasing the speed of response of the equipment under control by the introduction of non-linear elements in the feedback system. Another objective has been determination of the response under rapidly changing (transient) conditions of these non-linear systems. His work has been unusually well received by the technical world, as evidenced by the number of papers accepted for publication in outstanding technical journals.

Dr. L. J. Lewis has spent much time in developing a network analyzer to be used by the University and by Northwest power utilities in making studies of the power network of the Northwest Power Pool. The only other instrument in the Northwest capable of doing this is owned by the Bonneville Power Administration and is generally unavailable to other utilities because it is used almost continuously in the solution of Bonneville problems. Dr. Lewis is attempting to design and build at a lower cost a more flexible analyzer which will be available, part time, to public utilities of the Northwest. This is a long-term project with only limited funds provided by the University; thus far no outside funds have been available.

Prof. F. R. Bergseth has conducted a program for developing new methods of relaying on power transmission lines, under the sponsorship of Bonneville Power Administration. The operation of the Northwest Power Pool requires a great many inter-ties between the different utilities which make up the pool and between individual power plants of any given utility. Whenever a power fault occurs, due, for example, to the shorting of a transmission line, it is extremely important that the faulted section of line be immediately isolated before the entire network falls apart. This can only be done by special relays which can tell whether the fault has occurred on the section of line which they are protecting or on another section which is merely being fed by the line under consideration. In the latter case the relay must hold in until the faulted line is cleared by its own protective relays. While relays to do this kind of work are now available, they are not entirely satisfactory, and Professor Bergseth has already developed some new types being tried out on the Bonneville system.

A number of other studies are in progress or are getting underway. Prof. F. D. Robbins has devoted time to the study of the problems of the Northwest Power Pool and has made recommendations for alleviation of the power shortage. Prof. G. L. Hoard is undertaking a project in cooperation with the Fisheries Department for electric guiding of fish around hydro-electric plants and through the fishways provided in the dam structure. Mr. A. B. Jacobsen has developed a number of electronic devices including instrumentation for recording earthquakes, and has given assistance to the Medical and Dental Schools and several other University departments.



Above: **Analyzer and Control Metering Desk.** *Below:* **Dr. L. J. Lewis at Panel of the Power System Network Analyzer.**

Research is not the only public service provided by members of the staff. Staff members have been active in many other fields, one of which is the support of their technical societies which promote the growth of engineering development and education. Members of the staff have served as local and national officers of the American Institute of Electrical Engineers and the Institute of Radio Engineers, and have been active on Institute committees. Two have served as members of the Chamber of Commerce committees studying the problems of Northwest power. One served for five years as a member of the Transportation Commission of the City of Seattle, operating the Seattle Transit System.

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PROF. H. M. SWARM AND ROBERT PERRY WITH MICROWAVE RECEIVING EQUIPMENT USED IN SURVEY FOR INTERISLAND RADIO COMMUNICATION

Power supplies and FM receiver are shown mounted in the trunk of the car. The portable tower with receiving paraboloid antenna is mounted on the rear bumper.

Photo courtesy EVERETT DAILY HERALD

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Graduate Theses: 1947-1953

BPA: Bonneville Power Administration Fellow
EES: Engineering Experiment Station Fellow
WE: Westinghouse Electric Company Fellow

M. S. in Electrical Engineering

1947

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AMER, S. H.: Calculation and Metering of Three-Phase Symmetrical Components.

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SMEAD, H. J.: Cathode Modulation.

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GRINICH, V. H.: A Square-Law Device Utilizing a Non-Linear Feedback Element.
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LOUIE, W.: A New Approach to the Analysis of the Direct Radio Loudspeaker.
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SWARM, H. M.: The Generation of Single-Sideband Suppressed-Carrier Radio Frequency Waves.
WHITING, J. H.: Thermodynamc Analysis of Ground-Coil Evaporators for Heat Pumps. (BPA)

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BOTHUN, R. B.: A Study of Series Capacitators Installed on Electric Transmission Lines with Particular Reference to Transient Overvoltages.
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HIEBERT, R. D.: Analysis and Application of the Cathode-Coupled Amplifier. (EES)
RUSSELL, G. M.: Microwave Mirrors: Experimental Verification of a Theory of Flat Reflectors Used in Conjunction with Centimeter-wavelength Antenna Systems.

1952

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LENNSTROM, C. O.: A Crossed Wave-Guide Directional Coupler for Use at Three Centimeters. (WE)
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MENKE, E. M.: Studies on the Economic Feasibility of Serving Residential Heating in the Pacific Northwest. (EES)
SCHOENMAN, R. L.: Automatic Methods of Dropping Interruptible Loads for the Improvement of System Stability. (EES)
WALL, R. E., JR.: A Method of Forming a Broad Band Microwave Frequency Spectrum. (EES)

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KOENIG, W. A.: Characteristics of a Microwave Metallic Delay Lens.
MORRIS, J. A., JR.: A Heat Pump for Sewage Digester Plants. (EES)
NANEVICZ, J. E.: Off-Axis Performance of Microwave Mirrors.
OLSON, D. M.: Torque-Saturated Second-Order Servomechanism Response.
SHAH, C. N.: Optimum Design of Simple Servomechanisms in the Presence of Random Disturbances Using the Root-mean-square Error Criterion. (EES)

M.S. in Engineering

1952

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Mechanical Engineering

B. T. McMINN
Executive Officer

B. T. McMinn

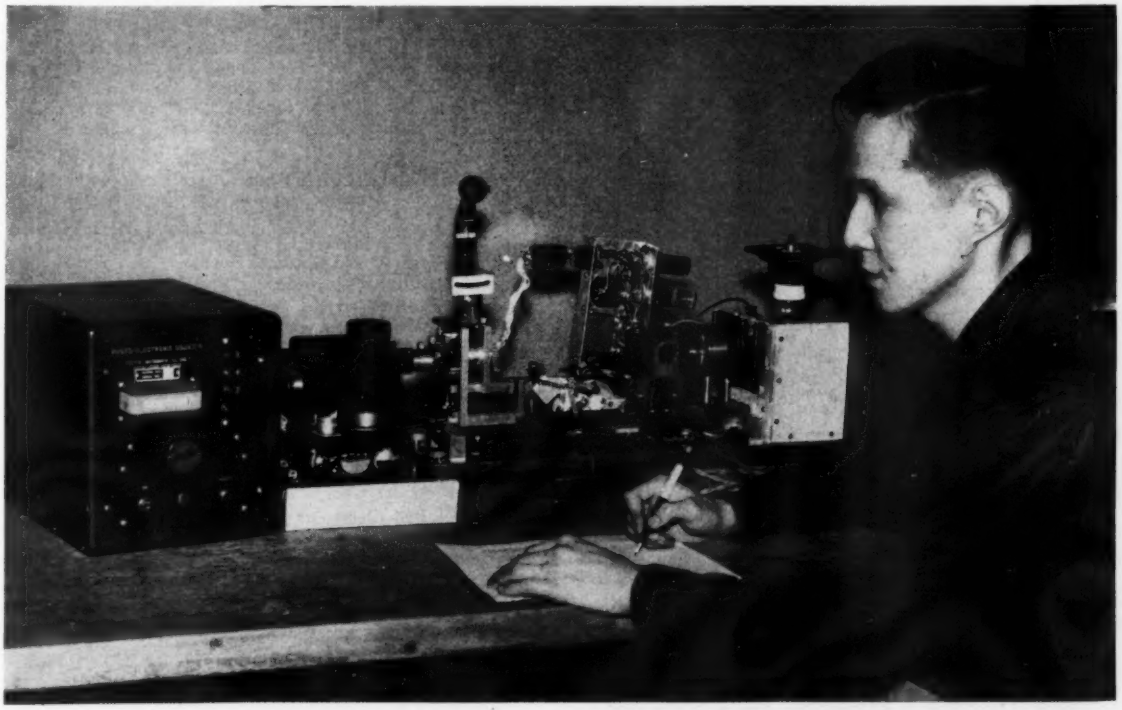
Practicing mechanical engineers are engaged in extremely diversified activities and it is essential that their academic training be on a very broad basis to reasonably equip them to enter any part of the field. The work of the Mechanical Engineering Department is organized around three main stems: machine design, power, and manufacturing processes, and the standard curriculum includes much basic material in all of these stems. A substantial number of electives allows the individual to develop particular interests and aptitudes, but not to the point of leaving "blind spots" in the fundamentals of the fields. While the faculty is largely made up of specialists, in building it a serious attempt has been made to obtain men of broad technical interests, men who will continually focus attention on the comparatively few fundamental principles underlying all work in the field. The correctness of the basic department philosophy with regard to curriculum and faculty is attested to by the successful careers of its graduates in extremely diversified fields.

One of the most noteworthy developments in the curriculum in recent years is the increased emphasis on the human and economic aspects of mechanical engineering. Material in established courses has been reorganized and new courses have been added in order to achieve the proper emphasis on these aspects of modern mechanical engineering. The department is now providing service courses in this field of

thought for all of the departments in engineering and for three other colleges of the University, under the following course titles: Engineering Administration, Engineering Economy, Quality Control, and Methods Analysis. The faculty has also been able to render valuable aid in this rapidly expanding field to government units and to private industry in recent years, through courses for particular groups and through consultation.

In addition to its work in instruction and research of its own, the faculty is continually active in serving the public in three ways, through consultation, through applied research and development of specific applications for both private and public bodies, and through participation in the activities of the various engineering societies. The number of research projects and publications of recent years gives an idea of the scope of the contributions of the faculty in research, development, and publications.

Specific examples of such contributions are the works of Professors Day, Hendrickson, and Schaller. Professor Day has directed the research of a number of graduate students in the field of experimental stress analysis, as well as carrying on projects of his own. In addition to several contributions to the technical programs of the Society for Experimental Stress Analysis, he has served on the national Papers Committee and as chairman of technical sessions. He served as chairman of the Western Washington Section of ASME last year, and is editor of the *Bulletin* of the Machine Design Division of ASEE. Professor Hendrickson has contributed many papers to the literature in *Air-Conditioning and Refrigeration* and is editor of the 1954 edition of the *ASRE Data Book*, in addition to serving on local and national committees of ASRE. The research work in the use of olivine as a foundry molding material carried on by Professor Schaller and associates has received international attention. The four phases which have been investigated so far are preparation from the ore, molding techniques, surface-finish control, and adaptation to the shell-molding process. Two aspects of this work which have made it of great public interest are the very much lessened health hazard and the fact that large deposits of olivine are found within the state. In addition to this continuing work in olivine, Professor Schaller has done significant research in arc-welding, and this year published the text, *Engineering Manufacturing Methods* (McGraw-Hill).



INTERFEROMETER FOR CALIBRATING STRAIN GAGES, DESIGNED AND BUILT BY A. S. KOBAYASHI, E.E.S. FELLOW, UNDER THE SUPERVISION OF PROF. E. E. DAY

Mr. Kobayashi is observing the fringe order as indicated by the electronic counter.

Publications: 1943-1953

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EGGLESTON, G. E., "Flame Propagation Velocities Under Pressure," *The Trend in Engineering*, Vol. 3, No. 2 (April, 1951). *(Grad. Student)*.

FOSS, O. A., "Water Injection in a Small Jet Engine," *The Trend in Engineering*, Vol. 2, No. 4 (Oct., 1950). *(Grad. Student)*.

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Graduate Theses: 1946-1953

M.S. in Mechanical Engineering

EES: Engineering Experiment Station Fellow

1946

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M.S. in Engineering

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OWENS, B. W.: Work Sampling by Regular Observations.

DO SCIENTISTS LACK DISCIPLINE?

"Toward the close of the recent war, in our atomic project we had a very heterogeneous group of scientists, engineers, Army and Navy men, and laborers. Though they were eager to do the job, it was not easy to get them working smoothly together. After a rather discouraging day, General Groves made this comment: 'Compton, you know, you scientists don't have any discipline.'

"I asked him, 'General, what do you mean?'

"He said, 'You don't know how to take orders and give orders.'

"I thought a minute before I replied, 'General, I suppose that's right. We don't know how to take orders and give orders. But we do have a different kind of discipline. You see, there isn't anybody who can tell a research man what it is that he should be doing. He's got to figure that out for himself. But when he's figured it out for himself, he's got to make himself do it. The difference between a good scientist and a scientist that isn't so good is whether he will make himself do the thing that he sees needs to be done'."

—A. H. COMPTON in "Case Histories:— Creativity in Science," Symposium on *"The Nature of Creative Thinking,"* Industrial Research Institute, May 5 ,1952.

Left

Upper: **Corner of the Ceramics Laboratory with electrodialysis cell, supercentrifuge, differential thermal analyzer.** *L. to r.:* **E. C. Rao, E.E.S. Fellow, and Dr. J. I. Mueller.**

Center: **H. J. Kelly at metallograph.**

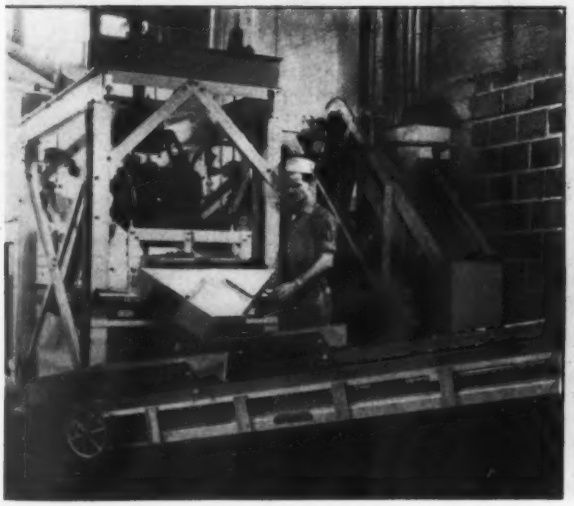
Lower: **Pilot plant for cleaning coal by heavy-media process.**

Right

Above: **Humphrey spiral concentrator.**

Below: **Oxyacetyline P.C.E. furnace.** *L. to r.:* **H. J. Kelly, K. G. Strandberg.**

(Last four photographs courtesy U. S. Bureau of Mines*)*



School of Mineral Engineering

DRURY A. PIFER
Director

D. A. Pifer

The demand for minerals and mineral products is insatiable. In the United States, industrial development and the individual's standard of living depend on an adequate and ever increasing supply of metals and minerals. The easily discovered deposits of ore from which metals may be extracted simply have been found and are nearly exhausted. Mineral deposits of ever diminishing quality must supply the future need. Our major sources of energy depend upon improved technology permitting the mining of narrower beds of coal, the discovery of deeper deposits of oil and gas, and more efficient means for total recovery of these minerals from the earth. Phenomenal growth in the demand for non-metallic minerals and products derived from them likewise requires new discoveries of source materials and careful investigation into their properties for suitability to commercial needs.

With the passing of the rich and abundant resources exploited during the past century, we are faced with the necessity of applying a higher degree of science and technology in all branches of the mineral industry. The first function of the School of Mineral Engineering is to develop men trained in these sciences and in their peculiar adaptation to the special physical and economic limitations found in the mineral industry. Concurrently with this activity, the faculty of the School, its graduate students, and the Northwest Experiment Station of the U. S. Bureau of Mines associated with the School, devote considerable attention to research on the scientific and technical problems of the industry. In both of these fields the School is an integral and important factor in the mineral and metallurgical industries of the state. Its contributions have been many, and some have been of national importance.

U. S. Bureau of Mines

In 1918, the Northwest Experiment Station of the Bureau of Mines was established in the laboratories of the School. Graduate students have assisted in much of the research of the Bureau in the twenty-five years during which the Station has been working cooperatively with the faculty of the School.

Notable among the Bureau's contributions are those in connection with the development of the Dutch State Cyclone as a device for classifying and thickening mineral pulp. This machine was introduced to North American mineral dressing from this campus in 1946, following observations by Dr. H. F. Yancey, Director of the Northwest Experiment Station, as a member of the Allied Forces Technical Mission. The machine has now found wide application in mineral concentration plants of every type and has become an important device for efficient mineral recovery.

The heavy-media process as applied to coal cleaning was developed in the University laboratories following its application to concentration of ore minerals in the early 40's. Earlier publication of the results of our graduate research resulted in the extension of this process into coal cleaning and also the erection of a plant based on this process at the mines near Bellingham, Washington.

The Humphrey spiral concentrator is a new machine that is included in our cooperative program. Experimental work done at this laboratory is the only published work on the fundamentals of this equipment and its application in particular to coal cleaning.

Earlier cooperative work included the development of a shaking table for coal cleaning, a process now in general acceptance throughout the industry. Fundamental work on mineral classification in hydraulic columns, the application of the froth flotation process to coal, and the application of pneumatic tables to coal cleaning have originated or been materially advanced by cooperative research at this School.

Work of a less spectacular nature has been done on the physical properties of mineral materials such as the coking quality of various coals, the development of field tests for coking ability, relative abrasiveness of coal and coke materials, phosphorus distribution in coal, sampling methods, and numerous other relatively obscure but important factors.

Ceramic, Metallurgical, and Mining Engineering

A strong research program in the division of ceramic engineering has been characteristic of this School. Many of the problems studied have been in cooperation with industry. Important among the investigations was the testing of many clays and shales from Washington as suitable source material for lightweight aggregate. Ultimately, several sources

were found and the products manufactured from them have been thoroughly tested, laying the basis for a new industry. Commercial production is expected shortly in both western Washington and near Vancouver, Canada. The study of the economics of locating a glass plant in this region was completed, and at the same time much assistance was given to the glass industry by the solution of various technical problems. Recent testing of a prestressed, full-sized ceramic structural unit initiated a country-wide boom in development of this new application to ceramic products.

Because of manufacturing difficulties, the Applied Physics Laboratory enlisted the cooperation of the ceramics faculty in developing an essential dielectric material and methods for its manufacture in order to produce locally items necessary to carry out their research projects. Of a more fundamental nature is current research on the physical structure of ceramic materials utilizing the X-ray diffraction which reveals the molecular arrangements and modifications in crystalline products. Studies made cooperatively with the Bureau of Mines on silica sands, diatomaceous earth, chromite refractories, olivine, and clay have all contributed to industrial development and technology in Washington. The development of olivine as the base for a new ceramic earthenware body, as well as its use as a refractory and as foundry sand is the culmination of fifteen years study of this material. The olivine deposits of this state found near Bellingham are unique in that this and the deposit in North Carolina are the only ones in the United States. The resource is enormous and the potentiality is difficult to measure.

The X-ray Analytical Laboratory of the School compares very favorably in equipment with that of any educational institution. Under the direction of Dr. J. I. Mueller, this laboratory is well prepared to take on any problems in X-ray diffraction or spectroscopy. In addition to normal class use, these facilities assist other departments within the University as well as industry.

National recognition has been accorded Dr. Mueller for his work, and he has appeared as lecturer at three different X-ray diffraction schools, twice in New York and last August in San Francisco. The work using X-ray spectroscopy to reduce time for analysis of ceramic materials from a matter of days to a few hours has been widely acclaimed. Currently, a high-temperature furnace is being developed for use with the X-ray diffraction equipment that will permit the studies of reactions at temperatures in excess of 2300° F.

The division of metallurgical engineering has had the physical metallurgical laboratories extensively revised and new research efforts are now beginning. Among the newer metals, cerium is coming to the fore. An extensive investigation was made of the effect of this metal on the physical properties of steel. An attempt was made to develop a new type of quenching media through the use of suspended solids in a liquid.

Current investigations include the effect of ultra-high-frequency vibration on the carburizing and nitriding rates of steel, and the phase changes taking place at the metal-sand contact in casting iron or steel in the foundry.

Most of the graduate work in mining engineering is done in cooperation with the Bureau of Mines and has been reviewed under that heading.

In addition to research programs and instruction, the faculty of the School of Mineral Engineering is constantly engaged in assisting mineral industries in solving more immediately pressing technical problems. The laboratories are utilized by many people during the year. With special knowledge and equipment available here, many of these services are performed as a part of an obligation to the citizens of the state by one of its civic institutions.

To facilitate the exchange of ideas and to inform the interested public about research at the University and in industry, the School sponsors and cooperates in presenting a number of technical meetings each year. For twenty-five years the Mineral Industries Conference has been a feature of the winter quarter. Many technical meetings have been held on the campus cooperatively with the American Ceramic Society, the American Institute of Mining and Metallurgical Engineering, the West Coast Mineral Association, the Pacific Northwest Ceramic Association, and the Coal Producers Association.

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SKINNER, K. G., "Diatomites of the Pacific Northwest as Filter-Aids" **(with A. A. Dammann, R. E. Swift, G. B. Eyerly, G. R. Shuck, Jr.),** U. S. Bur. Mines Bull. 460 (1944).

SUBBARAO, E. C., "Use of Alkali-fluoro-silicate Enamel for Aluminum," *Finish*, Aug., 1952. *(Grad. Student).*

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YANCEY, H. F., "The Cyclone as a Thickener of Coal Slurry" **(with M. R. Geer),** *Trans.*, Am. Inst. Min. and Met. Eng., Vol. 177 (1948). Discussion, *ibid.*

Graduate Theses: 1946-1953

EES: Engineering Experiment Station Fellow
EOJ: Edward Orton, Jr. Fellow in Ceramic Engineering
USBMC: U.S. Bureau of Mines (and School of Mineral Engineering) Cooperative Fellow

M.S. in Ceramic Engineering

1946

TYRRELL, M. E.: Refractory Uses of Pacific Northwest Chromites.

1947

GANGLER, J. J.: A Study of Ceramic Materials in Relation to Their Use in Jet Propulsion Engines.

MCKINNELL, J. F.: Hawaiian Lava as a Potential Ceramic Raw Material.

TIBBALS, H. L.: Secondary Expansion of Pacific Northwest Refractories.

1948

BAUMANN, H. N.: Refractory and Furnace Studies.

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WEINTRAUB, D. L.: The Properties of Electrical Porcelain Bodies Formulated from Pacific Northwest Raw Materials. (USBMC)

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VARAVARN, U.: The Physical Properties of Electrical Porcelain Bodies Formulated from Pacific Northwest Raw Materials. (USBMC)

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WEN, TAN.: A Study of Leadless Wet-Process Cast Iron Enamels.

1951

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VAN FOSSEN, R .W.: Vibrational Comminution of Resistant Materials. (USBMC)

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VALIA, B. H.: Hot Pressing of Low Fusion-Point Clays.

WATT, C.: Reheat Load Test of Refractory Brick.

M.S. in Metallurgical Engineering

1948

KROHA, A. J.: The Centrifugal Cyclone Thickener. (USBMC)

1949

ELDER, B. R.: Production of Anode Carbon from Coal.

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KASHYAP, V. C.: Production of Anode Carbon from Coking Coals of Washington and Utah.

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BAUER, E. E.: Sigma Phase and Its Resistance to Corrosion at Elevated Temperature.

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YEASLEY, J. W.: Microradiographic Study of the Copper-Copper Oxide System. (USBMC)

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GILBERT, Y. D.: The Metallurgy and Welding of 17-7PH Stainless Steel.

YIM, W. M.: An Investigation of the Quenching Characteristics of Heavy Media. (EES)

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HANSSON, ANTS: Influence of Ultrasonics on Carburizing.

M.S. in Mining Engineering

1947

FARNUM, L. B.: Electrostatic Cleaning of Coal.

GORING, A. W.: Refractory and Petrographic Properties of Pacific Northwest Chromites.

KELLY, HAL J.: Some Refractory Properties of a Northwest Zircon Concentrate.

1948

MORROW, J. G.: The Beneficiation and Utilization of Deer Harbor Soda Feldspar. (USBMC)

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BROWN, J. E.: Design of a Pilot Plant Utilizing the Dutch Cyclone with a Non-Magnetic Medium. (USBMC)

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GRIFFITH, R. F.: Economic Geology of Peacock Mountain, Okanogan County, Washington.

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DUBOIS, R. L.: Continuous Operation of Rod Mills at Sub-Critical Speeds.

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BRIBER, A. A.: An Analysis of Some of the Factors Influencing Washery Performance. (USBMC)

COCHRANE, T. S.: Heavy-Pitch Methods of Mining Coal.

DREVDAHL, E. R.: The Application of Froth Flotation and Agglomeration for Improving the Efficiency of the Humphreys Spiral for Cleaning Fine Coal. (USBMC)

KLEIN, M. J.: Specific Gravity Measurement of Heavy Media Suspensions. (USBMC)

REIM, K. M.: Washington Salines as a Ceramic Flux. (USBMC)

1952

SCHWARTZENBERG, W. L.: A Study of the Properties of Magnetite Suspensions. (USBMC)

1953

DAVIS, F. C.: The Effect of Clay on the Stability of Magnetic Suspension. (USBMC)

CORRECTION

In the July issue of *The Trend*, the legend under Figure 2, page 6, should read: "Mr. Gene Salveson of the Builders Brick Company." Mr. Salveson is not associated with the Seattle Brick Company.

NEW PROJECTS

Project No. 144. Drying of Sewage Sludge. R. G. Tyler, Professor of Sanitary Engineering, Supervisor; G. H. Hansen, Research Fellow.

Project No. 145. Particle Orientation in Viscous Liquid Flow. J. H. Mackin, Professor of Geology, Supervisor; John Kolars, Research Fellow.

Project No. 146. Heat Transfer from Solid-Liquid Suspension. R. W. Moulton, Professor of Chemical Engineering, Supervisor; A. P. Miller, Research Fellow.

Project No. 147. Transient Response of Power System Relays. L. J. Lewis, Associate Professor of Electrical Engineering, Supervisor; T. K. Maitra, Research Fellow.

Project No. 148. Low Lag Air Speed Systems for Airplanes. V. M. Ganzer, Professor of Aeronautical Engineering, Supervisor; P. C. Wingrove, Research Fellow.

Project No. 149. Cooperative Triaxial Test Project. R. G. Hennes, Professor of Civil Engineering, Supervisor.

Project No. 150. Thermodynamic Properties of Aniline. J. L. McCarthy, Professor of Chemical Engineering, and W. B. Nordquist, Assistant Professor of Mechanical Engineering, Supervisors; J. L. Lienhard, Research Fellow.

Project No. 151. Equilibrium Studies of the System Na_2O-CO_2-H_2S-H_2O. A. L. Babb, Assistant Professor of Chemical Engineering, Supervisor; K. L. Mai, Research Fellow.

Project No. 152. Diffusion Studies in Non-Ideal Binary Liquid Systems. A. L. Babb, Assistant Professor of Chemical Engineering, Supervisor; C. C. Caldwell, Research Fellow.

FREEDOM IN RESEARCH

"Dr. C. E. K. Mees, Director of Research at the Eastman Kodak Company, once made a pertinent comment . . .: 'The best person to decide what research is to be done is the person who is doing research. The next best is the head of the department. After that you leave the field of best persons and meet increasingly worse groups. The first of these is the research director who is probably wrong more than half the time. Then comes a committee which is wrong most of the time. Finally, there is the Committee of Company Vice-Presidents which is wrong all the time.' It may surprise you to hear me say from Washington that I believe in simplicity of organization, less bureaucracy, and much less building of empires of research and administration. We would do well to heed Zinsser's words in which he cautioned about the danger of the administrative camel crowding the intellectual pilgrim out of his tent."—"Freedom and Finance in Research," ROGER D. REID, ONR, Washington, quoted in *Am. Scientist*, April,, 1953.

Department of Geology

HOWARD A. COOMBS
Executive Officer

H. A. Coombs

The facilities of the Engineering Experiment Station have been used in a great variety of ways to further research in geology. Titles published in *The Trend* pertaining to geology range from vibration studies at Ross Dam, or glacial maps of Seattle, to synthesis in the incipient stages of granitization. Perhaps most important of all are the contributions made toward the development of electronic recording devices for our seismometers.

In each case the cooperative work with the Engineering Experiment Station has provided a quantitative approach to the problems of geology. So often sufficient quantitative data are lacking in geological studies to provide an adequate basis for conclusions.

The work at Ross Dam gave measured intensities of blasts up to 800 pounds of dynamite per blast. The intensities were measured within a few hundred feet, or less, of the blasts. This is one of the very few articles in the literature giving some measurement of energy from blasts in rock.

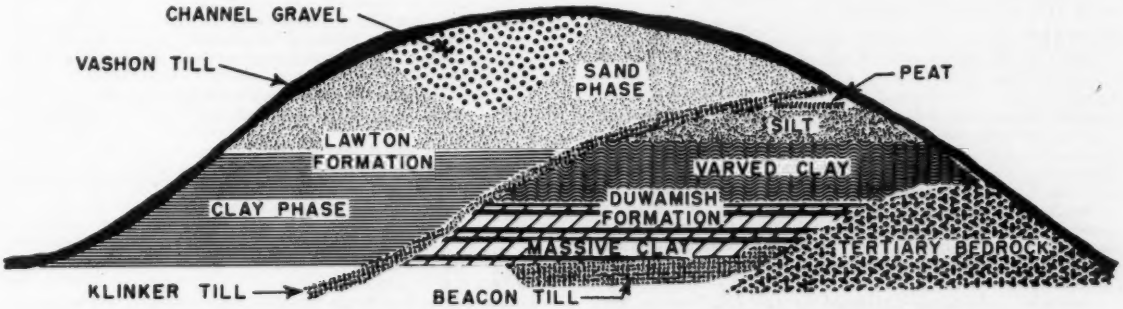
The glacial map of Seattle is the result of painstaking detailed mapping of outcrops in the metropolitan area. With the great amount of construction of new highways, tunnels, buildings, etc., in Seattle, the map has been a great help to engineers and contractors, many of whom have requested copies of the complete report on the glacial geology of Seattle as embodied in the M.S. thesis of W. R. Stark and D. R. Mullineaux, Engineering Experiment Station Fellows. It is hoped that this report may be the forerunner of a more extended investigation dealing with the engineering properties of various foundational materials occurring in the Seattle area.

Several contributions have been made in the field of seismology. For the first time we have a map showing the gravity anomalies in western Washington. This information was eagerly used by the many oil companies seeking petroleum deposits in Washington.

An entirely new system was devised for recording and presenting seismographic data. Standard sound-recording magnetic tape was used to record the three components of earth displacement during an earthquake. This new system can operate 17 days without attention and is ideal for outlying seismograph stations.

An electronic system has recently been devised which will record all three components of earth movement by pen and ink on paper tape. This enables the operator to examine the seismogram immediately; in fact he can watch the record being made by an earthquake. Like most modern seismograph stations, the University of Washington had used photographic paper for recording earthquakes. The paper must be developed before the seismogram is visible. Usually this is done at the end of each 24 hours run. With the new pen-and-ink recording, the record can now be inspected immediately, and the source of the earthquake located.

In sharp contrast to the above studies an investigation was made on the synthesis of an incipient stage



DIAGRAMMATIC CROSS SECTION SHOWING POSSIBLE COMPLEXITY OF A SEATTLE HILL

of granitization. Arkosic sandstone was placed in a pressure bomb and heated with an open system setup so that a steam solution could pass through a thin wafer of the rock. As a result of this hydrothermal action, some of the finer portions of the rock recrystallized. Perhaps this represents an initial stage toward the complete granitization of a sediment. Again the quantitative information, in regard to temperature and pressure, is most important.

The net result of these studies shows that the Engineering Experiment Station has successfully removed departmental boundaries and allowed a free interchange of ideas among the various disciplines. The geologists have worked with civil, electrical, mechanical, and chemical engineers toward a common goal. Because of this cooperation we in geology have gained a great deal of valuable information and at the same time feel a debt of gratitude to our associates in engineering.

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CREATIVE THINKING AND THE "IMAGINATIVE LEAP"

"In modern times the people who have taught us what is pure fact are those philosophers known as the British empiricists, men like Bishop Berkeley and David Hume. Einstein once told me that it was his reading of David Hume that made him aware that he did not have to account for the experimental facts of mechanics by Newton's concepts and laws. Newton himself had an erroneous conception of the validity of his theory, as is shown by his own words, 'I make no hypotheses. I have deduced the principles of my physics from the observed facts.' We know that this was false. If he had deduced his theory, it could never be replaced by Einstein's theory. . . .

"As Einstein again said to me, 'Bishop Berkeley was truly a genius. It is relatively easy to realize that you don't directly observe scientific objects, that you don't directly observe electrons, or electromagnetic waves, etc., but it took a genius to realize that you don't even observe common sense objects, that you don't observe tables and chairs'."

"On the basis of what we observe, this audience might just as well now be sitting looking at a screen. All that is needed to make possible our present experience is that some sound waves convey the same patterns and some light rays reflect the same visual images. When we view a moving picture film, although we see that the people are there and hear the automobiles there, we do not believe they are there as external objects. . . . Thus to infer the external public object from the sensuous qualities, which are all that the senses give us, we have to make an imaginative leap even for common sense objects.

"There is no real difference between knowing tables and chairs and knowing electrons. The tables and chairs are no more given as pure facts than are the electrons. All that is given as pure fact are sensuous qualities. . . . The scientific man finds that if he just postulates or infers common sense objects, they are not subtle enough to account for all the sense qualities that nature presents to him. Then he must postulate more subtle objects. Thus he builds his common sense table up first out of molecules. Then he builds his molecules out of chemical atoms, and then he builds his chemical atoms out of electrons and protons and even more subtle scientific objects. Note that none of these things are directly observed. They are all inferred from what is directly observed."—F. S. C. NORTHRUP in "Philosophy's Statement of the Problem of Creativity," Symposium on *"The Nature of Creative Thinking,"* Industrial Research Institute, May 5, 1952.

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UNIVERSITY OF WASHINGTON

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